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Macroeconomics With Frictions

S. Rao Aiyagari
Research Officer
Research Department
Federal Reserve Bank of Minneapolis

Abstract

This article is a progress report on research that attempts to include one type of market incompleteness and frictions in macroeconomic models. The focus of the research is the absence of insurance markets in which individual-specific risks may be insured against. The article describes some areas where this type of research has been and promises to be particularly useful, including consumption and saving, wealth distribution, asset markets, business cycles, and fiscal policies. The article also describes work in each of these areas that was presented at a conference sponsored by the Federal Reserve Bank of Minneapolis in the fall of 1993.

The dominant modeling approach in macroeconomics so far has been to assume that markets in an economy are *complete* and *frictionless.* Economists using this approach have assumed, in other words, that in the economy they are studying, markets exist for all possible trades that any individual might want to make, at any date and under any possible contingency, and that these markets operate without any *frictions;* individuals can buy and sell as much as they want in any market at given prices—without any constraints on borrowing in credit markets, for example, or on short sales in asset markets—and without any transaction costs.[1]

While admittedly quite inconsistent with the characteristics of actual economies, this modeling approach has been the best macroeconomists have been able to use, and the approach has generally worked pretty well. Yet some puzzles it has simply not been able to solve. Apparently, for some issues, the incompleteness and frictions in actual economies are crucial. So another modeling approach, one that incorporates these characteristics, is necessary—and thanks to recent computational advances, some progress has been made in developing such an approach.

To promote more progress, the Federal Reserve Bank of Minneapolis last year sponsored a conference which brought together much of the significant recent work of this type. The particular form of market incompleteness/frictions focused on at the conference is the absence of insurance markets in which individual-specific risks may be insured against. In this paper, I explain in detail why this modeling approach can be expected to have a significant impact on answers to questions of interest to macroeconomists and national policymakers. I provide some specific examples of topics in which this research has been or promises to be especially useful. I describe the contributions made by the papers presented at the Minneapolis Fed's conference. And I describe what I see as the most fruitful directions for future research of this type.

The Focus

The reason for focusing on insurance markets is that, when compared with the standard approach, models with incompleteness and frictions in these markets are likely to have significantly different and empirically plausible implications for a variety of issues of interest to macroeconomists and policymakers.

The new modeling approach incorporates the empirically plausible notion that individuals face substantially greater uncertainty at the individual level than that represented by fluctuations in aggregate variables like per capita consumption or per capita income—the types of fluctuations incorporated by standard models. Per capita consumption is notoriously smooth (fluctuating on average less than 1 percent from trend), and per capita income is only somewhat more variable (fluctuating on average less than 2 percent from trend). In contrast, individual earnings can fluctuate on average as much as 25 percent from trend. Presumably, the reason for the substantially greater uncertainty at the individual level is the inability to fully insure against individual-specific risks. For otherwise individuals would face no more uncertainty than that represented by fluctuations in per capita consumption or per capita income. In turn, the substantial uncertainty faced by individuals must have important implications for consumption, saving, asset accumulation, and portfolio behavior.

In addition to this substantially greater uncertainty faced by individuals, the new modeling approach includes market frictions like borrowing and short-sale constraints and transaction costs. These seem ubiquitous features of observed markets which make individuals' budget constraints quite different from what they would be otherwise. Generally speaking, such frictions can introduce kinks, nonlinearities, and even nonconvexities into individuals' budget constraints.

Some Sample Topics

Thus, the combination of incomplete insurance markets and frictions is likely to lead to significantly different positive and normative implications than the implications of standard models with complete and frictionless markets. I will illustrate this by giving some examples of issues of interest to macroeconomists and policymakers.

Consumption and Saving

The behavior of individual as well as aggregate consumption and saving has been an important research topic for macroeconomists. With complete insurance markets, individuals can fully insure idiosyncratic variations in their earnings. Therefore, individual consumptions will not respond to individual-specific shocks to earnings, but only to aggregate shocks which affect per capita consumption. In fact, individual consumptions will be perfectly correlated with each other and with per capita consumption, and each individual's consumption will vary as much as anyone else's and as much as per capita consumption. There is a wealth of empirical evidence strongly at variance with these implications and suggesting that individuals' consumption and saving behavior is strongly influenced by the uncertainty they face due to the inability to fully insure earning fluctuations.

Friedman's (1957) permanent income theory of consumption was the first attempt to explain the dependence of an individual's consumption on the individual's earnings when the opportunity exists to save and dissave at a constant interest rate. Implicit in this formulation is the view that this individual is part of an economy composed of a large number of such individuals whose earnings fluctuate randomly in an idiosyncratic fashion (that is, uncorrelated across individuals) and that insurance markets in which individuals could have fully insured away their earning fluctuations are absent.[2] If the utility function is quadratic, consumption is not restricted to be nonnegative, and the interest rate equals the utility discount rate (Sargent 1987, chap. 12), then it can be shown that consumption in any period equals the consumer's *permanent income*, that is, the annuity value of the consumer's wealth. Therefore, consumption responds strongly to permanent changes in earnings and only weakly to temporary changes in earnings. Further, consumption responds only to previously unanticipated news about permanent income, so changes in consumption from one period to the next are unforecastable.

A key feature of the permanent income theory of consumption is *certainty equivalence*—that is, the idea that the consumer's behavior depends only on the conditional expectation of future earnings, not on any other features of the distribution of earnings.[3] Leland (1968), Sandmo (1970), and Dreze and Modigliani (1972) were among the first to analyze the dependence of the individual's consumption/saving choice on the riskiness in future income.

In the context of a two-period problem, they show that whether the person consumes less and saves more or consumes more and saves less in response to riskier future earnings depends on the third derivative of the utility function. If the third derivative is positive—that is, the marginal utility of consumption is convex—then an increase in the riskiness of future earnings causes the consumer to consume less and save more. This extra saving reflects the desire of consumers to protect themselves against low future earnings and has been termed *precautionary saving*.[4]

Both the permanent income theory and the theory of precautionary saving ignore liquidity constraints by permitting consumption to be negative. Yet casual evidence suggests that many consumers are constrained in their borrowing and that this affects their consumption behavior in a way different from the predictions of the theories of permanent income or precautionary saving. If consumption has to be nonnegative and individuals face uncertainty in their future earnings (due to incomplete insurance markets), then individuals will be subject to borrowing constraints. This happens because, if their debt is too high, then there is some chance that they may have to default in the event that their future earnings remain unexpectedly low for a number of periods. Therefore, individuals will face binding constraints in how much they can borrow.

The presence of borrowing constraints has a significant effect on individual consumption behavior. When an individual's assets get too low and the individual cannot borrow, that person's consumption responds strongly to even temporary changes in earnings. However, when assets are high and the individual is a saver rather than a borrower, the person's consumption responds only weakly to temporary changes in earnings.[5]

This kind of behavior at the individual level can have repercussions at the aggregate level as well. When a significant fraction of households are close to being borrowing-constrained, a bad aggregate shock can cause these households to cut back significantly on consumption spending. Consequently, under some conditions, aggregate consumption may respond rather strongly to certain types of aggregate shocks relative to the predictions of a model with complete insurance markets or one without borrowing constraints.

At the aggregate level, the combination of a precautionary saving motive and a borrowing constraint leads to a higher capital stock and aggregate saving rate (Laitner 1979, 1992; Bewley, undated).[6] It has been suggested that these factors may be quantitatively significant contributors to aggregate saving (Zeldes 1989, p. 289). Further, incomplete insurance market models with borrowing constraints can lead to a well-defined stationary distribution of wealth characterized by a lot of mobility of individuals across the wealth distribution. Thus, such models can potentially address facts concerning the wealth distribution and mobility in addition to aggregate saving.[7]

Wealth Distribution

The study of how society's wealth distribution is determined at a point in time as well as over time is a topic at the core of arguments concerning the trade-off between equity and efficiency. Empirical evidence suggests that incomplete insurance markets are crucial in understanding these issues.

With complete insurance markets, an individual's position in society's wealth distribution does not vary much over time or across states of the world. With complete insurance markets, there would be no rags-to-riches or riches-to-rags stories of individual fortunes and misfortunes.

However, evidence suggests considerable mobility of individuals across the wealth and income distributions. According to Avery and Kennickell (1989), 60 percent of U.S. households were in a different wealth decile in 1985 than in 1982. Approximately 30 percent moved up, and 30 percent moved down. Only people in the topmost and bottommost deciles were more likely to stay put than to move to a different decile. If insurance markets were complete and had no frictions, it would be hard to explain the movement of large fractions of households across the wealth distribution over such a short period of time (suggesting that the movement is not due to age and life-cycle related factors). Sawhill and Condon (1992, p. 3) report that, in the United States, in both the 1970s and 1980s, "some three out of five adults changed income quintiles. A little less than half the members of the bottom quintile moved up into a higher quintile, and about half the members of the top quintile fell out of that quintile."

With incomplete insurance markets, there is typically a trade-off between equity and efficiency. For instance, proportional taxes distort incentives but also promote equity by providing insurance.

For normative analyses of equity/efficiency trade-offs, it is important to specify explicitly the information structure of an economy that precludes complete insurance and then see what allocations are compatible with resource and information constraints.[8] This is because the information constraints have significant implications for what policies are or are not feasible.

Green (1987) shows how to address an infinite-horizon problem of insurance with private information.[9] In his economy, there are a large number of individuals receiving idiosyncratically random endowment shocks which are privately observed. He characterizes the evolution of the distributions of wealth and consumption and shows how the optimal resource- and information-constrained allocation can be supported by the trading of bonds.

Work in this area is continuing and promises to enhance our understanding of the dynamics of wealth distribution and the trade-off between equity and efficiency (Atkeson and Lucas 1992, 1993, references therein).

Asset Markets

Asset markets are an area where a new modeling approach has been badly needed, for it is probably fair to say that the attempts to understand various aspects of asset markets through the lens of complete and frictionless market models have failed.

Perhaps the most dramatic of these failures is the inability to explain the observed equity premium (the excess average return on stocks over the return on short-term Treasury bills) and the risk-free rate (the average real return on short-term T-bills). The average annual real return on 90-day U.S. T-bills over the period 1948–78 is less than 1 percent. On stocks over the same period, this return is about 7 percent. (These data are from Labadie 1989, p. 289.) However, using the complete frictionless market approach, Mehra and Prescott (1985) find that the largest equity premium they can generate in a model of this type is 0.35 percent per annum; the corresponding risk-free rate is about 4 percent per annum. These results lead Mehra and Prescott (1985, p. 145) to conclude that the observed returns cannot be "accounted for by models that abstract from transactions costs, liquidity constraints and other frictions absent in the Arrow-Debreu set-up" (by which they mean the standard approach).

Recent work with models of incomplete insurance markets, borrowing and short-sale constraints, and transaction costs has been promising on this front. (See, for example, Aiyagari and Gertler 1991, Heaton and Lucas 1993.) Because of the precautionary demand for assets in such models coupled with borrowing constraints, the risk-free rate will be lower in them than in complete frictionless market models. Transaction costs in trading in equity markets can generate a transaction/liquidity premium on stocks relative to T-bills.

Incomplete insurance market models with transaction costs are also potentially capable of explaining other features of asset markets that are anomalies in the context of complete insurance market models. For instance, in the standard type of models, there is no role for asset trading, and the models make no predictions regarding transaction volumes and transaction velocities of different assets. This is clearly at odds with the large volume of transactions that take place daily in asset markets and with the pattern of transaction velocities and returns across assets with low-yielding, liquid assets having higher transaction velocities than higher yielding, less-liquid assets. Addressing these facts is particularly relevant for understanding the desirability of policies which attempt to reduce the volatility of asset markets by taxing asset market transactions, for example.

Incomplete insurance market models with frictions are also potentially capable of explaining the observed disparities in portfolio compositions across individuals. With complete insurance markets, every individual would hold some amount of risky assets with favorable returns. If individuals' risk aversion coefficients were not too different, then all individuals would hold roughly similar portfolios. Both of these predictions are, of course, wildly at odds with the facts.

The evidence on portfolios indicates considerable diversity in portfolio compositions for households with different wealth levels. Mankiw and Zeldes (1991) present evidence that only about 25 percent of U.S. households own any stocks in spite of the fact that the expected return on stocks has been so much higher than the risk-free rate. According to evidence presented by Avery, Elliehausen, and Kennickell (1988), the ownership of stocks is highly concentrated at the top end of the wealth distribution, whereas the ownership of liquid assets is concentrated in the bottom end of the wealth distribution.[10] The portfolios of households with low wealth contain a disproportionately large share of low-return risk-free assets and a disproportionately small share of high-return risky assets. The portfolios of high-wealth households exhibit the opposite characteristics.[11]

Such wide disparities in portfolio compositions would be hard to explain under complete frictionless markets if individuals have roughly constant and equal relative risk-aversion coefficients. And understanding the diversity in portfolio compositions is important for analyzing the distributional impact of policies which affect the relative returns on different assets.

Business Cycles

Another area benefiting from the new modeling approach is business cycle analysis. The sources of business cycle fluctuations and the economic mechanisms by which shocks are propagated over time are fundamental topics in research on business cycles. There has been a resurgence of interest in this area following the work of Kydland and Prescott (1982). They show that a version of the representative-agent growth model (which belongs to the class of complete frictionless market models) with technology shocks can generate fluctuations which resemble those of the postwar U.S. economy. Since Kydland and Prescott's (1982) contribution, there has been skepticism regarding the importance of technology shocks and the plausibility of the mechanism through which their model propagates shocks. It has been noted, for example, that the dynamics of output in their model closely resemble the dynamics postulated for the technology shocks and that the economic mechanism of the model itself appears to contribute very little to the propagation of the shocks (Rouwenhorst 1991).

Recently, there have been attempts to incorporate credit market frictions into business cycle models in order to provide an alternative propagation mechanism, in particular, to show how such frictions can lead to persistent fluctuations even if the sources of the fluctuations are not persistent (Williamson 1987, Bernanke and Gertler 1989). These analyses are based on the costly state verification model introduced by Townsend (1979) which considers an environment in which a potential insurer can only monitor the state of the insuree at some cost.[12]

Williamson (1986) uses a model of a credit market with this feature to show how it could lead to borrowers being credit-rationed. It could happen that some borrowers are denied credit at the going interest rate and could not obtain credit even if they were to offer to pay a higher rate.[13] Williamson (1987) embeds this framework in a dynamic model and shows how this feature could lead to business cycle fluctuations even though such fluctuations would not arise in the absence of this feature.

Bernanke and Gertler (1989) also embed the costly state verification framework in a dynamic model to show how this feature can lead to business cycle fluctuations which are persistent. Their emphasis is on the net worth of borrowers/investors. A good shock to aggregate output raises borrower net worth, lowers lender monitoring costs, and thereby increases the quantity of loans and investment. This raises future output and, thereby, the net worth of future borrowers/investors and thus generates a persistent increase in output.

The nonrobustness of the implications of representative-agent models of business cycles and the small costs of business cycle fluctuations implied by these models have been troublesome. For example, very small costs of adjusting the capital stock from one period to the next in some versions of these models can lead to drastically different implications for the relative volatilities of consumption and investment (Cochrane 1989). Further, typically these models imply very small costs of business cycle fluctuations and, hence, very small potential benefits from policies eliminating business cycle fluctuations (Lucas 1987).

However, with incomplete insurance markets, the business cycle implications are likely to be more robust to small costs of adjusting the capital stock since the total uncertainty faced by individuals is substantially greater. For exactly the same reason, the welfare costs imposed by the additional uncertainty due to aggregate shocks is likely to be larger than when there are complete insurance markets and individuals face only aggregate uncertainty, but no individual uncertainty (İmrohoroğlu 1989). It follows that the potential gains to smoothing aggregate fluctuations is also larger.

Fiscal Policies

The implications for government fiscal policies are quite different in models with incomplete insurance markets and borrowing constraints than in the standard models.

In the new models, even when interest on government debt is financed by lump-sum taxes, the level of government debt need not be neutral with respect to consumption, investment, and welfare. Government debt serves a liquidity purpose, and an increase in government debt, in effect, loosens the borrowing constraint on individuals and can improve welfare. Permanent increases in the level of government debt raise the real interest rate, crowd out private capital, and reduce private consumption. Permanent increases in government consumption affect not only private consumption, but also investment and the real interest rate.

These results stand in contrast to those in the standard representative-agent growth model with lump-sum taxes in which government debt is completely neutral and permanent changes in government consumption (with inelastic labor supply) reduce private consumption one-for-one and have no effect on investment or the real interest rate.

Another implication of incomplete insurance markets and borrowing constraints for fiscal policy is the general desirability of taxing capital income even in the long run as part of an optimal tax program (Aiyagari 1994). This is quite unlike models with complete and frictionless markets in which it is generally undesirable to tax capital income in the long run (Chamley 1986). Using a standard model, Lucas (1990b) argues that the welfare gains of eliminating the capital income tax in the U.S. economy are quite large. The results on optimal fiscal policy for models with incomplete insurance markets and borrowing constraints cast doubt on whether such gains exist.

Furthermore, in some versions of models in which the growth rate of the economy is endogenously determined (for example, Jones and Manuelli 1990), changes in government debt or government consumption can affect the growth rate of the economy when insurance markets are incomplete even though with complete insurance markets there would be no growth rate effects. Thus, the welfare costs of higher government debt and government consumption may be significantly larger with incomplete markets than with complete markets.

Caution

While the above discussion might suggest a rather negative view of complete frictionless market models, that view should be resisted. The neoclassical representative-agent growth model (which belongs to the class of complete frictionless market models) has provided a powerful framework for analyzing a variety of questions about growth, business cycles, and monetary and fiscal policies.[14] It has provided many useful qualitative insights, and its application to business cycles, following the work of Kydland and Prescott (1982), has been quantitatively somewhat successful. Even though many economists feel that incomplete markets and a variety of frictions are rather important, the representative-agent growth model continues to enjoy popularity, primarily because it is relatively easy to obtain qualitative and quantitative predictions from versions of this model. When insurance markets are incomplete and there are some frictions, these tasks turn out to be far more difficult due to the analytical and computational complexities of such models.[15] Recent advances in computation have, however, narrowed this edge, so that incomplete insurance market models with frictions can be investigated more fruitfully.

The Conference Papers

The papers presented at the Minneapolis Fed conference last fall cover theoretical, computational, and quantitative aspects of macroeconomic models with incomplete insurance markets and some frictions.[16] The areas of application include all those I have described above.

Consumption and Saving

In my conference paper, I try to quantify the importance of the precautionary saving motive and borrowing constraints for aggregate saving. I find that moderate values of risk aversion, variability, and persistence in individual earnings generate very small increases in the aggregate saving rate relative to the representative-agent model—usually less than three percentage points. These quantitative results stand in contrast to some earlier suggestions on the importance of precautionary saving. For example, Zeldes (1989, p. 289) has conjectured that "a significant fraction of the capital accumulation that occurs in the United States may be due to precautionary savings." I also show that in this class of models in which individuals face substantial uncertainty, the welfare gain to an individual of participating in asset markets can be quite large. This is in contrast to the very small welfare gains calculated by Cochrane (1989) in a representative-agent model. I also show that the model generates greater inequality in wealth than in income, which is consistent with the data.

Wealth Distribution

Phelan presents a theoretical analysis of wealth distribution when only one side to a contract can make binding long-term commitments—for example, firms can be legally bound by long-term promises, but workers cannot.

The motivation here is that in the models of Green (1987) and Atkeson and Lucas (1992), which assume that everyone can make binding long-term commitments, the wealth and consumption distributions get more and more unequal as time passes. In Atkeson and Lucas' model, individuals receive idiosyncratic taste shocks which are private information. The intuitive reason for the increasing inequality in consumption is roughly as follows. In order to get someone who has a low desire for current consumption to truthfully reveal that information and contribute some resources that can be used to provide extra consumption to those who have a high desire for current consumption, one needs to compensate the person by offering rewards in the future. When someone claims to have a high desire for current consumption, that person is given some extra current consumption, but in order to discourage false claims, future penalties are attached to such claims. Thus, the optimal incentive scheme tends naturally to generate greater and greater inequality as time passes.

In Phelan's model, the absence of long-term commitment on one side of a contract means a person can always walk out of that contract and be free to start a new one with someone else. This provides a floor below which people cannot be pushed and results in a nondegenerate wealth distribution. Thus, this paper makes a contribution to the theory of the dynamics of wealth distribution with private information. Its empirical implications are somewhat more attractive than those of some earlier theories.

Asset Markets

Den Haan proposes a computational algorithm for solving an incomplete insurance market model with aggregate shocks and with borrowing and short-sale constraints and uses it to study the quantitative significance of these features for asset pricing. A significant contribution of this paper is the computational procedure itself. As was noted previously, such models present severe computational difficulties because the distribution of wealth and portfolios is a state variable of the economy which evolves stochastically in response to aggregate shocks.

Business Cycles

Krusell and Smith also propose a computational algorithm for solving a growth model with incomplete insurance markets, aggregate shocks, and a variety of frictions. In addition to making a contribution toward computational techniques for such models, the authors use the model to analyze the robustness of the model's aggregate time series implications to small changes in the modeling environment. This issue is motivated by the analysis of Cochrane (1989) referred to earlier, which suggests that the aggregate time series implications of representative-agent models are quite nonrobust to the introduction of small costs of, say, adjusting the capital stock. Since the welfare gains from optimally accumulating and decumulating capital as opposed to holding a fixed amount of capital at all times are small, it follows that a small fixed cost of adjusting the capital stock would lead the representative agent to keep the amount fixed. This leads to a drastically different implication for the relative volatilities of consumption and investment. In contrast, Krusell and Smith find that the aggregate time series implications of their model are much more robust to introducing small fixed costs of changing behavior.

Kiyotaki and Moore present a theoretical analysis of how large and persistent cyclical fluctuations can arise when borrowers are limited in how much they can borrow by the value of their collateral assets. This paper makes an important and novel contribution to the problem of why business cycle fluctuations are so persistent. It shows that the dynamics induced by the interdependence between collateral values and investment naturally generate persistent cyclical fluctuations.

Caballero and Engel attempt to reconcile the lumpy and intermittent behavior of investment at the firm level with the smoother behavior of investment at the industry level, thereby providing an improved explanation of investment dynamics at the industry level. Firms receive idiosyncratically random and uninsurable investment opportunities and face nonconvex costs of adjusting their capital stock. The optimal investment policy for the firm is of the (S,s) type; that is, the firm lets its capital run down to the level s, at which time the firm undertakes investment designed to bring its capital stock up to the level S. Caballero and Engel generalize this policy by allowing the trigger levels (S,s) to vary randomly across firms and randomly over time for a firm. This generalization captures the realistic and empirically important features that firms do not always wait for the same stock disequilibrium to adjust and adjustments are not always of the same size.

Fiscal Policies

Krusell and Ríos-Rull analyze the quantitative importance of taxation (motivated by redistribution) for capital accumulation. In this model, individuals are heterogeneous ex ante, differing in initial wealth. There is a tax on savings, and the tax rate is determined via majority voting. The surprising finding of this paper is that small changes in the initial wealth distribution have quite large effects on long-run output. Thus, this paper makes a contribution to the growing literature on political economy and shows that political economy considerations can be quite powerful.

Lastly, S. İmrohoroğlu analyzes the positive and normative consequences of different tax structures involving various combinations of labor, capital, and consumption taxes in a life-cycle model with incomplete insurance markets and borrowing constraints. One contribution of this paper is showing how to compute steady states of overlapping-generations models with incomplete insurance markets and borrowing constraints. The main substantive finding of this paper is that a shift away from capital income taxation toward labor income taxation has much smaller welfare gains in an incomplete market model with frictions than in the representative-, infinitely lived agent model used by Lucas (1990b). This calls into question the strong quantitative support Lucas has put forward toward eliminating capital income taxation.

Future Work

There are mainly two directions in which progress needs to be made in the study of incomplete insurance markets with frictions.

One is to improve further the computational methods for analyzing incomplete insurance market models which also contain aggregate shocks. Aggregate shocks are needed in these models, for example, to address questions about the equity premium and business cycles. The papers by den Haan and by Krusell and Smith are a good start, but have some limitations. In these papers, the distribution of the idiosyncratic shock is approximated by a two-state Markov chain, which is likely to be inadequate (Tauchen 1986).

Having more states is computationally burdensome because one needs to compute the wealth and portfolio distributions for each possible realization of the idiosyncratic shock. If n variables are used to describe the wealth distribution, then each additional state for the idiosyncratic shock contributes an additional n variables in the state space of the economy, which makes the state space quite large.

Adding more assets also makes the computation more burdensome because one needs to approximate the joint distribution of assets for each realization of the idiosyncratic shock. The number of variables needed to approximate a joint distribution of assets will likely increase faster than the number of assets since covariances also enter the joint distribution.

Unfortunately, extending the computational methods for more assets is probably necessary since recent models of the monetary transmission mechanism have emphasized the uneven distribution of monetary injections across households and markets (Grossman and Weiss 1983, Rotemberg 1984, Lucas 1990a). Any model of a monetary economy with heterogeneous agents and aggregate shocks will involve at least two assets: money and bonds or money and capital. A monetary model which has capital and hopes to address the equity premium question will necessarily involve three assets.

The other direction in which progress is needed is to extend theoretically as well as computationally the recent attempts to provide an information-based approach to incomplete insurance (Green 1987, Atkeson and Lucas 1992). This work is important for questions involving wealth distribution and equity/efficiency trade-offs. Further, and as has been noted earlier, recent models of business cycles with financial propagation mechanisms are based on optimal contracting in environments with private information (Williamson 1987, Bernanke and Gertler 1989).

Incomplete insurance market models with frictions have the potential to satisfactorily address a number of questions of interest to macroeconomists and policymakers. The computational and analytical difficulties involved are not trivial, but the payoffs are likely to be worthwhile. There is a great deal of difficult but exciting work ahead.

[1]It is not straightforward to distinguish between market incompleteness and frictions, as this description implicitly suggests. Sufficiently high costs of transacting in a particular market might lead to the market being inactive and, hence, effectively, absent. Market incompleteness and frictions might also arise from informational problems. For instance, if individual incomes are private information and, hence, unverifiable, then it may be impossible to provide any insurance against the risks that individuals face. If there are adverse selection problems (different groups of individuals have different risk characteristics which are private information), then some groups may be prevented from buying as much insurance as they would like.

[2]If we abstract away from aggregate shocks for now, it follows that because of the large number of individuals there will be no uncertainty in aggregate earnings. This justifies the assumption that the interest rate is nonstochastic since prices and interest rates reflect aggregate information and aggregate information is nonstochastic. The further assumption that the interest rate is constant over time may be justified by focusing on a steady state in which the distribution of assets across individuals is constant over time. The determination of the interest rate would be a problem requiring a general equilibrium analysis, and this would come later. There is a considerable literature which applies and tests the permanent income theory of consumption to aggregate consumption and earnings. In this context, the assumption that the interest rate is constant can only be justified by assuming that there is a storage technology which yields a constant return. This is not plausible. The assumption that the interest rate is independent of aggregate earnings is quite a stretch and is unlikely to be a good approximation, unlike the assumption that the interest rate is independent of an individual's earnings. Thus, it is not clear whether the empirical failures of the permanent income theory of consumption when tested using aggregate data really have much bearing on how good the theory is or simply reflect how bad the assumption is regarding the constancy of the interest rate or, more generally, its independence from aggregate earnings.

[3]This is also known as the *separation principle.* The consumer's problem can be separated into one part which involves replacing current and future earnings by their conditional expectations and solving the resulting deterministic problem and another part which involves computing these conditional expectations given the stochastic process of earnings.

[4]Caballero (1990) analyzes the implications of precautionary saving for consumption in an infinite-horizon model assuming that the utility function is a negative exponential function; that is, $U(c) = -\exp(-Ac)$, where A is the coefficient of absolute risk aversion. Kimball and Mankiw (1989) use a model of this type to analyze some issues in fiscal policy.

[5]The classic analysis of consumer behavior with uncertain earnings and a borrowing constraint is by Schechtman and Escudero (1977). Sibley (1975) and Miller (1976) extend the analysis of precautionary saving to the case with a borrowing constraint. They show that if the marginal utility of consumption is convex, then an increase in the riskiness of earnings reduces consumption and raises saving at each level of assets. The borrowing constraint becomes relevant if the interest rate is less than the utility discount rate. If the interest rate exceeds the utility discount rate, then the individual wants to be a lender and the borrowing constraint is irrelevant. Further, if the interest rate is negative, some limit on borrowing must be imposed; otherwise, the consumer's wealth is infinite, and nothing prevents the consumer from enjoying an infinite amount of consumption. It turns out that general equilibrium considerations ensure that the equilibrium interest rate will be less than the utility discount rate, so that the borrowing constraint always plays a role.

[6]Aiyagari, forthcoming, contains an exposition of general equilibrium capital accumulation models with incomplete insurance markets and borrowing constraints as well as references to related literature. It should be pointed out that once borrowing constraints are taken into account, the convexity of the marginal utility of consumption is irrelevant for generating higher aggregate saving.

[7]It should be pointed out that in the permanent income and precautionary saving theories, which ignore borrowing constraints, the distribution of wealth becomes more and more unequal as time passes, and there is no well-defined stationary wealth distribution.

[8]In many incomplete insurance market models, insurance markets are simply ruled out by fiat. No economic reason is given for why they would not arise if they were not prohibited.

[9]Townsend's (1982) analysis of multi-period contracting models with private information is a key contribution in this area. He shows how in the presence of private information a multi-period contract can be desirable over a sequence of one-period contracts.

[10]Avery, Elliehausen, and Kennickell (1988) say, for example, that the top 1 percent of U.S. wealth holders own about 60 percent of all equity, but only about 10 percent of all liquid assets. In contrast, the bottom 90 percent of households own about 53 percent of all liquid assets and only about 9 percent of all equity. Greenwood (1983) presents similar evidence to the effect that the top 5 percent of U.S. wealth holders own about 85 percent of all corporate stocks and about 60 percent of all debt instruments (Table 4, p. 35, and Fig. 2, p. 34).

[11]Kessler and Wolff (1991) calculate that the lowest wealth quintile's portfolio contains over 80 percent liquid assets (currency, demand deposits, and time deposits), only about 9 percent financial securities and corporate stocks, and only about 3 percent other real estate (not including housing) and unincorporated business. In contrast, the highest wealth quintile's portfolio contains only about 15 percent liquid assets, about 22 percent financial securities and corporate stocks, and over 42 percent other real estate and unincorporated business (Table 6, p. 263). Similar evidence is presented by Mankiw and Zeldes (1991).

[12]This feature precludes full insurance since if full insurance were to be offered, then the insurer would have to monitor every one of the insuree's possible states, and this would be costly. Under some conditions, the optimal contract has the features of a debt contract. Whenever the insuree declares a realization lower than some cutoff level, the insuree is monitored and the insurer takes everything. The cutoff level may be thought of as a promised payment, and the declaration of a lower realization may be interpreted as default or bankruptcy on the part of the insuree. Whenever the insuree declares a realization higher than the cutoff level, the insuree is not monitored and makes a fixed payment to the insurer. Gale and Hellwig (1985) adapt the costly state verification model to analyze credit contracts.

[13]The reason is that a borrower who offers to pay a higher rate is one who will likely default more often without close monitoring, and this leads to higher monitoring costs to the lender and, thereby, a lower return net of monitoring costs to the lender.

[14]The representative-agent assumption is fairly innocuous. Even if there are many ex ante different agents, the competitive equilibrium allocation solves a social planning problem in which the social planner maximizes a weighted sum of the utilities (over individual consumption and leisure streams) of the different agents. This weighted sum of utilities can be used to transform the model to a representative-agent model in which the representative agent's preferences over aggregate consumption and leisure streams depend on the weights different individuals receive.

[15]The computational difficulties arise for the following reason. Incomplete insurance markets imply ex post heterogeneity among agents; that is, even if all agents start out the same, they will not remain the same. Therefore, the distribution of assets among agents is an additional state variable for the economy, and one needs to solve for the equilibrium law of motion of the distribution of assets among agents simultaneously with solving an individual's optimization problem. Having a distribution function as part of the state vector complicates the computational burden enormously since a distribution function is potentially an infinite-dimensional object. Further, computing the solution to an individual agent's problem is significantly more difficult than computing the solution to a representative-agent business cycle model, for two reasons: (1) The extent of uncertainty faced by individuals in the incomplete insurance market models is much greater than that faced by the representative agent, who is only subject to aggregate uncertainty. Consequently, the commonly used linear (or log-linear) approximation (to the decision rules) around the nonstochastic steady-state method for the representative-agent model does not work very well; and (2) there is no borrowing and lending going on in a representative-agent model. Hence, there is no need to worry about binding borrowing constraints as there is in incomplete insurance market models. This imparts a high degree of nonlinearity to an agent's asset accumulation decision rule and is another reason why the linear (or log-linear) approximation method works poorly.

[16]See the Appendix for abstracts of the papers written by the authors themselves and a list of the people who attended the conference. Copies of the papers are available from their authors.

Appendix

Conference Papers and Participants

Here are summaries of the papers presented last fall at the Minneapolis Fed conference described in the preceding paper. These summaries are written by the authors of the papers.* Following the summaries is a list of the people who attended the conference.

The Papers

Uninsured Idiosyncratic Risk and Aggregate Saving

S. Rao Aiyagari
Research Officer, Federal Reserve Bank of Minneapolis

This paper studies the quantitative importance of the precautionary saving motive and borrowing constraints for aggregate saving and welfare. This study is motivated by the debate concerning the sources of aggregate capital accumulation, in particular, the suggestion that precautionary saving may be a quantitatively important component of aggregate saving.

The paper uses the standard growth model of Brock and Mirman (1972), modified to include a role for uninsured idiosyncratic risk and liquidity/borrowing constraints. This is done by having a large number of agents who receive idiosyncratic shocks to their individual labor productivities, which are uninsured, as in the models of Bewley (1986, undated). This class of models involves a considerable amount of individual dynamics, uncertainty, and asset trading, which is the main mechanism (in the models) by which individuals attempt to smooth consumption. However, aggregate variables are unchanging. This contrasts with representative-agent models in which individual dynamics and uncertainty coincide with aggregate dynamics and uncertainty. Due to the market incompleteness—that is, missing insurance markets—in combination with the possibility of being borrowing-constrained in future periods, agents accumulate excess capital in order to smooth consumption in the face of uncertain individual labor incomes.

The results of this paper suggest that the contribution of uninsured idiosyncratic risk to aggregate saving is quite modest, at least for moderate and empirically plausible values of risk aversion, variability, and persistence in earnings. The aggregate saving rate is higher by no more than three percentage points. However, for sufficiently high variability and persistence in earnings, the aggregate saving rate could be higher by as much as seven or even fourteen percentage points.

Some additional implications of the analysis are as follows. In contrast to representative-agent models (Cochrane 1989), it turns out that access to asset markets is quite important in enabling consumers to smooth out earnings fluctuations. In one example, by optimally accumulating and decumulating assets, an individual can cut consumption variability by about half and enjoy a welfare gain of about 14 percent of per capita consumption or about 8 percent of per capita income, compared to a situation in which the individual has no access to asset markets.

The model is also consistent, at least qualitatively, with certain features of income and wealth distributions. The distributions are positively skewed (median less than mean), the wealth distribution is much more dispersed than the income distribution, and inequality as measured by the Gini coefficient is significantly higher for wealth than for income.

Repeated Moral Hazard and One-Sided Commitment

Christopher Phelan
Assistant Professor of Economics, University of Wisconsin, Madison

Many economic relationships are characterized by differing abilities of parties to commit to long-term contracts. In labor markets, while an employer could conceivably sign a contract that offered a worker a job for life (and face legal sanctions upon reneging), a worker cannot sign a contract promising to never quit or work for another firm. Likewise, while an insurance company can promise no coverage for a customer or raise premiums beyond a set schedule, a customer cannot promise to never switch to another insurance company. In credit markets, banks have a much greater ability to commit to long-term credit arrangements with borrowers than borrowers have with banks. This paper considers markets where players on one side of the market, *firms,* have an unlimited ability to commit to long-term contracts, while players on the other side of the market, *agents,* have no ability to commit to long-term contracts.

Models of long-term contracting given moral hazard (or incentive problems) have been used to create theories of the distribution of consumption. (See Green 1987, Phelan and Townsend 1991, and Atkeson and Lucas 1992.) One problem with these earlier works is their extreme results regarding the long-run or limiting distribution of consumption. If consumption is bounded, all agents eventually become as rich or as poor as possible, and if consumption is not bounded, almost all agents eventually are arbitrarily rich or poor.

This paper attempts to achieve more realistic long-run results by modeling an individual's inability to fully commit to contracts which they wish to renege on later. In this model, agents receive an unobserved endowment at each date which they wish to insure (as in Green 1987). However, this paper (unlike Green's) assumes that individuals can leave one insurer and contract with another when they find it in their interest to do so. This puts an endogenous lower bound on how poor an individual can get and allows for a more realistic limiting distribution of consumption.

Solving Heterogeneous Agent Models: An Application to Asset Pricing With Incomplete Markets

Wouter J. den Haan
Assistant Professor of Economics, University of California, San Diego

In several areas of economic research, it has been pointed out that explicit modeling of the differences between agents is crucial for understanding economic phenomena. Examples can be found in growth theory, relating economic growth and income inequality; in monetary theory, using an asymmetric distribution of the monetary injection across the population; and in asset pricing, trying to explain risk premia by the lack of complete markets. It is also well known that combining the heterogeneity with a dynamic stochastic environment is a challenging problem. The intuition for the difficulty is the following. In a dynamic model, the optimal policy rules of the agents depend on the agents' state variables, which include variables that help predict future prices. Part of the set of state variables is, therefore, the distribution of wealth and other characteristics of the population. Moreover, in the presence of aggregate shocks, this distribution will change endogenously over time, and in general, this distribution cannot be restricted to belong to a specific class. The space of the state variables is thus much larger than in dynamic models using the representative-agent assumption. This paper extends the method of parameterized expectations to deal with this problem. In particular, I approximate the distribution by percentiles or by a set of moments. By increasing the number of included percentiles or by increasing the number of moments, the accuracy of the algorithm is increased.

In this paper, I use the algorithm to study short-term interest rates in a heterogeneous-agent economy with incomplete markets. First I look at examples in which agents are ex ante identical, but different realizations of the stochastic income process cause the agents to be different ex post. Consequently, their accumulations of wealth and their consumption streams are different. Then I analyze the importance of borrowing constraints, the supply of government bonds, the number of agents, and the persistence of the stochastic shocks. I also look at examples in which agents are different ex ante. Examples are economies in which agents differ because they have different levels of risk aversion, face a different stochastic income process, or use different information sets.

I argue that the addition of incomplete markets by itself cannot generate substantial premiums in asset markets. I also show that the result found in the literature that borrowing constraints are effective in generating premiums disappears if there is a positive supply of government bonds. A promising positive result of this paper is that substantial premiums are possible in models in which only a small fraction of the agents face a (very) high variability in income.

The Stochastic Growth Model With Heterogeneous Agents, Uninsurable Risk, Aggregate Uncertainty, and Fixed Costs of Flexible Behavior

Per Krusell
Assistant Professor of Economics, University of Pennsylvania

and Anthony A. Smith, Jr.*
Assistant Professor of Economics, Carnegie Mellon University

It is often claimed that economic agents follow simple behavioral rules. We hypothesize instead that agents are fully rational but do face costs of fully flexible behavior. We then ask how the introduction of such costs into the stochastic growth model alters the model's aggregate time series predictions. A variety of recent research suggests that the introduction of such costs can lead to dramatic changes in the dynamic behavior of the stochastic growth model. The purpose of this paper is to subject these findings to closer scrutiny by considering model economies with a richer microeconomic structure than the representative-agent, complete market models hitherto used. In particular, we characterize equilibria for economies where there is a multitude of consumers facing both aggregate risk and substantial idiosyncratic, uninsurable risk.

The specific model economy which we analyze is the standard one-sector stochastic growth model with exogenous, but stochastic labor supply: agents face a first-order Markov process for individual employment. In addition, there is an aggregate productivity shock, also following a first-order Markov process. Insurance markets are absent; the only insurance is that which can be accomplished using asset accumulation. We assume that agents incur a resource cost for not following an inertial rule. Specifically, we focus on two kinds of inertial rules: one in which adjusting capital is costly and one in which deviating from a prespecified saving rate is costly. In other words, in each period each agent must decide whether to pay a fixed cost and behave in an unrestricted way or to use the simple rule at no cost.

For the economy described above, the relevant aggregate state consists not only of the current value of the aggregate productivity shock, but also of the entire distribution of capital holdings in the economy. We address this potentially large computational problem by restricting individual consumers to use a small number of moments of the capital distribution to forecast the future behavior of the economy's prices. The computational results are striking: in all of the approximated equilibria, the agents in the economy are able to make close to perfect forecasts using a linear law of motion for the mean of the capital distribution.

The substantive results of the paper are that, where idiosyncratic risk plays a quantitatively important role, the introduction of small costs—less than 0.1 percent of consumption—of sophisticated behavior does not alter the model's aggregate predictions by more than a small amount. The main quantitative predictions of the representative-agent model are quite similar to those coming out of our framework.

Credit Cycles

Nobuhiro Kiyotaki*
Visitor, Federal Reserve Bank of Minneapolis
and Associate Professor of Economics, University of Minnesota

and John Hardman Moore
Professor of Economics, London School of Economics

This paper is a theoretical study into how credit constraints interact with aggregate economic activity over the business cycle. In particular, for an economy where credit limits are endogenously determined, we investigate how relatively small, temporary shocks to technology or income distribution might generate large, persistent fluctuations in output and asset prices. Also, we ask whether sector-specific shocks can be contagious, in the sense that they spill over to other sectors and get amplified through time.

For this purpose, we construct a model of a dynamic economy in which credit constraints arise naturally, due to the fact that lenders cannot force borrowers to repay their debts unless the debts are secured. In such an economy, fixed assets such as land, buildings, and machinery play a dual role: they are not only factors of production; they also serve as collateral for loans. Borrowers' credit limits are affected by the price of the collateralized assets. And at the same time, the price of these assets is affected by the size of the credit limits. The dynamic interaction between credit limits and asset prices turns out to be a powerful transmission mechanism by which the effects of shocks persist, amplify, and spill over to other sectors.

Explaining Investment Dynamics in U.S. Manufacturing: A Generalized (*S,s*) Approach

Ricardo J. Caballero*
Assistant Professor of Economics, Massachusetts Institute of Technology

and Eduardo M. R. A. Engel
Assistant Professor of Economics, Harvard University

In this paper, we derive and implement a model of aggregate investment that builds from the intermittent and lumpy investment behavior of firms facing nonconvexities in their adjustment technology. We try to learn from aggregate empirical lags about the likely structure of microeconomic adjustment costs. At the same time, we use the underlying theory to interpret these lags, their instability, and their implications for standard empirical investment equations.

At the microeconomic level, models of intermittent and lumpy adjustment have been extensively developed within the (*S,s*) literature. Here we generalize these models so the adjustment trigger barriers vary randomly across firms and for a firm over time. This modification introduces the realistic and empirically important features that units do not always wait for the same stock disequilibrium to adjust and adjustments are not always of the same size.

Empirical models of aggregate dynamics with heterogeneous microeconomic units that adjust intermittently have also been developed recently. Econometric implementation of these models requires observing a measure of the aggregate driving force; in the current context, this amounts to constructing a cost of capital measure. But undoubtedly many of the problems of the empirical investment literature are due to the difficulties of constructing a proper measure of the cost of capital, and even if this could be accomplished, such a variable is likely to be plagued by simultaneity and omitted variables problems. We circumvent these problems by proposing a nonlinear time series method that requires information only on the investment series itself and on the generating process of the driving force (but not on its realization). Somewhat analogously with the standard procedure of estimating convex adjustment cost parameters from the first-order serial correlation of investment, we learn about more complex and realistic lumpy adjustment cost functions from the structure of investment lags and their changes over time.

We estimate nonlinear dynamic panel data models for the investment/capital ratios of two-digit U.S. manufacturing industries during the period 1948–92. We find clear and widespread evidence in favor of our generalized (*S,s*) model over simple linear models. Our structural interpretation of this evidence suggests that resizing equipment and structures has an average cost of 11–12 percent of the value of the old stock and that 95 percent of the realizations of the adjustment cost are below 35 percent of the value of the old stock.

Distribution, Redistribution, and Capital Accumulations

Per Krusell and José-Víctor Ríos-Rull*
Assistant Professors of Economics, University of Pennsylvania

What is the role of the initial distribution of wealth in determining an economy's capital accumulation path? Posed in the context of a standard neoclassical growth model where agents have identical, constant relative risk-aversion preferences and access to a complete set of asset markets, the answer is, None. In this paper, we consider the same setup, but assume that a political mechanism allows agents to tax for redistributive reasons. Our main goal is to make a quantitative assessment of this model's implications for how the wealth distribution affects the growth path.

We use the one-sector growth model in its simplest form: the aggregate production function is Cobb-Douglas in capital and labor effort, and sustained growth is not feasible. The population consists of infinitely lived agents who are all identical except in their initial holdings of capital, and there are a finite number of types with respect to the initial wealth. Taxes have the form of a proportional income tax, the proceeds of which are rebated lump-sum. The policy determination process is one in which in each period there is a vote on the tax rate applied to current saving. The voter takes into account how the current policy affects the law of motion of the distribution of wealth and how it alters future policies. The equilibrium has the property that the political preference of the median type coincides with the policy outcome. The model is calibrated to U.S. growth properties, and the politico-economic equilibrium is computed numerically.

We find that redistribution of initial capital has surprisingly large effects on subsequent capital accumulation. Our estimates of the percentage change in long-run output following an initial redistribution of 1 percent of the total initial capital stock range between 1.3 and 21.7 percent, implying a great sensitivity of the capital accumulation path to the wealth distribution. For example, an initial redistribution away from the median voter implies that the tax rate increases, and the economy starts on a path toward a new steady state with higher taxes and lower total capital (in total as well as for each type) than if there had been no redistribution. The key is that any redistribution affecting the potential net transfer of the median voter is quantitatively important in this agent's voting decision: if a higher tax rate implies a higher net transfer, then in general the agent is likely to favor this higher tax even though it implies distortions.

An important finding is that the time period over which the current tax rate is voted matters: long periods make the taxes respond less to the changes in the initial distribution of capital. We interpret this finding as informative about institutions. Tax institutions where taxes are allowed to change (that is, are voted on) frequently lead to higher taxes on average and lower capital levels.

A Quantitative Analysis of the Optimal Tax Structure Under Incomplete Markets

Selahattin İmrohoroğlu
Assistant Professor of Economics, University of Southern California

This paper investigates the optimal tax structure in an overlapping-generations model with lifetime uncertainty, idiosyncratic income risk, and borrowing constraints. Taxing capital income is not desirable in this model because of the distortion on private saving and the consequent negative impact on the capital stock, aggregate output, and aggregate consumption. Taxing labor income is also not desirable, despite the inelastic supply of labor, since an increase in the labor income tax would hinder the individuals' ability to self-insure and to provide for old-age consumption. Since the individuals are liquidity constrained, higher labor income taxes make it more likely that the constraints are binding.

The model economy is calibrated to match certain features of aggregate U.S. data, and numerical methods are used to solve the individuals' finite-state, finite-horizon, discounted dynamic programs and to compute steady-state equilibria. The benchmark economy is one in which there is taxation of labor income (and unemployment insurance benefits) and capital income. The exogenous government purchases, which provide no utility to the individuals, and endogenously determined government transfer payments are held constant in the face of tax reform. Different tax reforms are examined. First, the tax on capital income is eliminated, and the labor income tax is increased. Second, the same amount of government purchases and transfer payments is financed by gradually eliminating capital income taxation or labor income taxation and introducing a tax on consumption.

The main finding is that moving away from capital income taxation toward labor income taxation yields a welfare benefit of 1 percent of aggregate consumption compared to the 6 percent benefit that Lucas (1990b) finds. Replacing the capital income tax with a higher tax rate on labor income redistributes resources away from the young working years during which borrowing constraints are more likely to bind. Furthermore, when individuals have access to a private annuity market to insure against lifetime uncertainty, the optimal capital income tax is 10 percent. Although eliminating this tax brings the economy closer to the golden-rule steady-state capital stock, which maximizes aggregate consumption, the simultaneous increase in the labor income tax rate produces an equilibrium consumption profile that is further away from that chosen by the social planner. A lower elasticity of intertemporal substitution in consumption increases the optimal capital income tax rate to 36 percent since the profile cost increases and the capital stock benefit decreases with a decline in the elasticity of substitution in consumption. When a consumption tax is made available, switching to consumption taxation becomes optimal. This is very much in line with a wide body of findings in the optimal tax literature. The welfare benefits of implementing this optimal tax plan are on the order of 2–4 percent of aggregate consumption. At the same time, a consumption tax leads to a worsening of inequality of wealth as measured by the coefficient of variation. Under any tax base, the variability in consumption is small relative to that in wealth.

The Participants

S. Rao Aiyagari
Federal Reserve Bank of Minneapolis

Beth Allen
Federal Reserve Bank of Minneapolis
and University of Minnesota

Fernando Alvarez†
Federal Reserve Bank of Minneapolis
and University of Minnesota

Joann M. Bangs†
University of Minnesota

Raphael V. Bergoeing†
University of Minnesota

John H. Boyd
Federal Reserve Bank of Minneapolis
and University of Minnesota

R. Anton Braun
Federal Reserve Bank of Minneapolis

Zuzana Brixiova†
University of Minnesota

Ricardo J. Caballero
Massachusetts Institute of Technology

Christophe Chamley
Universite Louis Pasteur

Nan-Kuang Chen†
University of Minnesota

Hsiao-Lei Chu†
University of Minnesota

Harold L. Cole
Federal Reserve Bank of Minneapolis

Wouter J. den Haan
University of California, San Diego

Antonia Diaz †
Federal Reserve Bank of Minneapolis
and University of Minnesota

Janice C. Eberly
University of Pennsylvania

Zvi Eckstein
Tel Aviv University

William B. English
Board of Governors of the
Federal Reserve System

Terry J. Fitzgerald†
Federal Reserve Bank of Minneapolis
and University of Minnesota

Julio Garcia Cobos†
Federal Reserve Bank of Minneapolis
and State University of New York, Stony Brook

Changzhen Gong†
University of Minnesota

Edward J. Green
Federal Reserve Bank of Minneapolis
and University of Minnesota

John C. Heaton
Massachusetts Institute of Technology

Thomas J. Holmes
Federal Reserve Bank of Minneapolis

Andreas Hornstein
Federal Reserve Bank of Minneapolis
and University of Western Ontario

Yin Hu†
University of Minnesota

Mark R. Huggett
University of Illinois

Ayşe İmrohoroğlu
University of Southern California

Selahattin İmrohoroğlu
University of Southern California

Ravi Jagannathan
Federal Reserve Bank of Minneapolis
and University of Minnesota

Nobuhiro Kiyotaki
Federal Reserve Bank of Minneapolis
and University of Minnesota

John P. Laitner
University of Michigan

Thanh T. Le†
University of Minnesota

Zheng Liu†
University of Minnesota

Deborah J. Lucas
Northwestern University

Robert E. Lucas, Jr.
University of Chicago

George McCandless
Federal Reserve Bank of Minneapolis
and Macalester University

Ellen R. McGrattan
Federal Reserve Bank of Minneapolis

Antonio Merlo
Federal Reserve Bank of Minneapolis
and University of Minnesota

Pedro Mira†
University of Minnesota

Arijit Mukherji
University of Minnesota

Christopher Phelan
University of Wisconsin, Madison

Freng Qi†
University of Minnesota

Bob Rebelein†
University of Minnesota

José-Víctor Ríos-Rull
University of Pennsylvania

Arthur J. Rolnick
Federal Reserve Bank of Minneapolis

David E. Runkle
Federal Reserve Bank of Minneapolis
and University of Minnesota

James A. Schmitz, Jr.
Federal Reserve Bank of Minneapolis

Anthony A. Smith, Jr.
Carnegie Mellon University

Nancy L. Stokey
University of Chicago

Christopher Telmer
Carnegie Mellon University

Garrett H. Teselle†
University of Minnesota

Joji Tokui
University of Minnesota
and Shinshu University

Marcelo Veracierto†
University of Minnesota

Yu-Lin Wang†
Federal Reserve Bank of Minneapolis
and University of Minnesota

Warren E. Weber
Federal Reserve Bank of Minneapolis
and University of Minnesota

*For papers with more than one author, an asterisk indicates which author presented the paper at the conference. Copies of the papers are available from their authors.

†A dagger by a name indicates that the person is a graduate student.

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